ONTARIO DRINKING WATER OBJECTIVES

Ontario

Ministry
of the
Environment

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ONTARIO DRINKING WATER OBJECTIVES

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PREFACE

This is the fourth revised edition of the Ontario Drinking Water Objectives, first approved by the Ontario Water Resources Commission on February 27, 1964. Previous editions were published in 1968, 1976 and 1978. The document is under continuous review, with amendments consolidated periodically and integrated into successive editions.

This edition recognizes and reflects the development of new knowledge and more sophisticated analytical techniques which permit the detection of contaminants heretofore unknown in the drinking water. In the light of this new knowledge and experience, it was necessary to re-assess the impact and potential hazards to human health of some of these substances in the drinking water.

The Guidelines for Canadian Drinking Water Quality, 1978, and its supporting documentation was used extensively in this revision. Maximum acceptable and target concentrations for radionuclides as well as maximum acceptable concentrations for other parameters directly related to health do not differ from those contained in the Canadian Guidelines. The aesthetic parameters do contain some values unique to the Province of Ontario.

The Provinces have jurisdiction over water supplies and in Ontario the legislation governing communal water systems is the Ontario Water Resources Act. In general, municipalities are responsible for both the inspection of plumbing and distribution of water. Where there is a public utilities commission that is responsible for the treatment and distribution of water, it acts as a statutory agent for the appropriate municipality, and the municipality therefore remains ultimately responsible for ensuring that a water of adequate quality is delivered to consumers.

Private operators of water supply systems falling under the Ontario Water Resources Act are also responsible for the quality of water at the consumers' tap. Water supplies not governed by the Ontario Water Resources Act are the responsibility of local health agencies.

The Ministry of the Environment obtains medical advice from medical experts in the Ministry of Labour and the Ministry of Health. Regional staff of the Ministry of the Environment

co-operate with local Medical Officers of Health in controlling potential health problems in community water supplies.

Construction of new water works or alterations to existing works may proceed only after a Certificate of Approval is issued by the Ministry of the Environment. Before issuing the approval certificate the Ministry must be convinced that the proposed works can provide drinking water of acceptable quality.

Regional staff of the Ministry of the Environment are responsible for ensuring that municipalities and private operators of water systems have appropriate monitoring programs based on recommendations contained in this publication.

The provision of a satisfactory supply of drinking water is, to a large extent, dependent upon the availability of sufficient quantities of high quality source water. While virtually any source water can, by treatment, be made suitable for drinking purposes, generally the more contaminated the supply, the greater the treatment cost and health risk.

Provisions for protection and enhancement of ambient water quality are outlined in the document entitled Water Management, Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment. The Water Management and Ontario Drinking Water Objectives publications are companion documents – the former containing **ambient water quality objectives,** the latter the **treated drinking water objectives**. Care should be taken not to confuse the two.

ACKNOWLEDGEMENTS

Editing and incorporating material during the writing of this revision was done by G. A. Missingham and a working group from the Water Technology Section, Laboratory Services and Applied Research Branch (formerly of the Pollution Control Branch). The comments and assistance received from regional staff of the Ministry of the Environment, staff of the Special Studies and Services Branch, Ministry of Labour and the Public Health Branch, Ministry of Health, the Ontario Section American Water Works Association, the Ontario Municipal Water Association and the Municipal Engineers Association of Ontario are gratefully acknowledged.

Revising Ontario's Drinking Water Objectives was made easier by the preceding work of the Federal/Provincial working group on revisions to the Canadian Drinking Water Standards and Objectives, 1968, and efforts of staff of Health and Welfare, Canada, who prepared criteria documents for Guidelines for Canadian Drinking Water Quality, 1978.

Although many persons contributed there are some who deserve specific mention because of their contributions. It is also useful to know who was closely involved in this revision for future reference during subsequent revisions.

The Microbiological Section was written by A. H. Vajdic, J. A Clark and L. Vlassoff, Ministry of the Environment with major contributions from S. Irwin, A Ley, G. Palmateer and H. Graham, Ministry of the Environment and Dr. D. Schiemann and Dr. T. P. Subrahmanyan, Ministry of Health.

The Radiological Section was written by Dr. H. Aitkin, Chief Radiation Protection Service, Ministry of Labour. Major contributors were K. Roberts, H. Graham, R. Hunsinger and A. James, Ministry of the Environment.

The Chemical and Physical Sections were arranged and edited by K. Roberts, R. Hunsinger, J. Dart, H. Graham, A H. Vajdic, A Oda, and M. Rawlings, Ministry of the Environment.

Many useful suggestions from C. F. Macfarlane, R. Watson, and G. H. Mills, Ministry of the Environment were adopted in this revision.

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1. INTRODUCTION

The primary purpose of drinking water objectives is for the protection of public health. Any water intended for human consumption should not contain any disease-causing organisms or hazardous concentrations of toxic chemicals or radioactive substances. Aesthetic considerations may also provide a basis for drinking water objectives since the water should be pleasant to drink. Temperature, taste, odour, turbidity and colour are all important in achieving waters which are aesthetically acceptable and pleasant to drink. Other aspects of water quality such as corrosiveness, tendency to form incrustations and excessive soap consumption should be controlled on the basis of economic considerations because of their effects on the distribution system and/or the intended domestic and industrial use of the water. The limits described in this document are considered to outline the minimum requirements necessary to fulfill the above objectives.

The document has been divided into a major section on health related water quality parameters and a section on characteristics related to aesthetic and other considerations. The final section deals with monitoring and surveillance for chemical, physical, bacteriological and radiological parameters. Tables 1, 1A, 2 and 3 list the limits for these parameters.

The appendices provide supporting documentation of the items listed in Tables 1, 1A, 2 and 3 in addition to providing information on other parameters which were studied and for which no specific limit could be established.

1.1 TYPES OF LIMITS

The following three types of limits shall be recognized:

Maximum Acceptable Concentration (MAC)

This term is used for limits applied to substances above which there are known or suspected adverse health effects. The presence in a drinking water of a substance at a level in excess of its maximum acceptable concentration shall be grounds for rejection of the water unless effective treatment is available. The length of time the maximum acceptable

concentration can be exceeded without injury to health will depend on the nature and concentration of the contaminant; however, no drinking water can be permitted to exceed these limits continuously.

TABLE 1
Maximum Acceptable Concentrations
Parameters Related to Health

Parameter*	Concentration (mg/L)
Arsenic	0.05
Barium	1.0
Boron	5.0
Cadmium	0.005
Chromium	0.05
Cyanide (Free)	0.2
Fluoride	2.4
Lead	0.05
Mercury	0.001
Nitrate (as N)**	10.0
Nitrite (as N)	1.0
Nitrilotriacetic Acid (NTA)	0.05
Pesticides	
(Aldrin + Dieldrin	0.0007
(Carbaryl	0.07
(Chlordane	0.007
(DDT	0.03
(Diazinon	0.014
(Endrin	0.0002
***(Heptachlor + Heptachlor Epoxide	0.003
(Lindane	0.004
(Methoxychlor	0.1
(Methyl Parathion	0.007
(Parathion	0.035
(Toxaphene	0.005
2,4-D	0.1
2,4,5-TP	0.01
Radionuclides****	—
Selenium	0.01
Silver	0.05
Trihalomethanes*****	0.35
Turbidity	1 FTU

*	Unless otherwise stated the limits for each substance refer to the sum of all forms present.
**	Where both nitrate and nitrite are present, the total nitrate plus nitrite-nitrogen should not exceed 10 mg/L.
***	When more than one of these pesticides is present, the "total pesticides" shall not exceed the sum of their MAC's or 0.1 mg/L whichever is the lesser.
****	Maximum acceptable concentrations and target concentrations for radionuclides can be found in Table 3, section 2.4.
*****	The term "trihalomethanes" comprises chloroform, bromodichloromethane, chlorodibromomethane, and bromoform, and their concentration as determined by the gas sparge or purge equivalent method (i.e. actual concentration) should not exceed 0.35 mg/L at any time.

Interim Maximum Acceptable Concentration (I.M.A.C.)

This term is used to describe limits for substances of current concern with known chronic effects in mammals and for which there are no established maximum acceptable concentrations. Although toxicological, epidemiological and health data are available for such substances the data are subject to public and scientific debate before agreement on a maximum acceptable concentration. The I.M.A.C. will generally be a conservative value subject to change as more precise information becomes available.

When a substance is detected at a concentration above its I.M.A.C., it will signal the need for more sampling and investigation. Requirements for corrective action will be on a case-by-case basis.

TABLE 1A
Interim Maximum Acceptable Concentrations
Parameters Related to Health

Parameter	Concentration (mg/L)
Polychlorinated Biphenyls	0.003
Uranium	0.02

Maximum Desirable Concentration (MDC)

This term is used for limits on substances which, when present at concentrations above the limits, are either aesthetically objectionable to an appreciable number of consumers or may interfere with good water quality control practices. These limits should not be exceeded whenever a more suitable supply or treatment process is, orcan be made available at a reasonable cost.

The chemical substances shown in Table 2 should not be present in a water supply in excess of the concentrations indicated where, in the judgement of the Ministry, other more suitable supplies are, or can be made available.

TABLE 2
Maximum Desirable Concentrations
Parameters Related to Aesthetic Quality

Parameter	Concentration*
Chloride	250
Colour	5 (TCU) **
Copper	1.0
Iron	0.3
Manganese	0.05
Methane	3 L/m³
Odour	Inoffensive
Organic Nitrogen***	0.15
Phenols	0.002
Sulphate	500
Sulphide	Inoffensive
Taste	Inoffensive
Temperature	15°C
Total Dissolved Solids	500
Total Organic Carbon	5.0
Zinc	5.0

* Unless otherwise indicated, the maximum desirable concentrations are expressed in mg/L.

** True Colour Units.

*** Total kjeldahl nitrogen minus ammonia nitrogen.

The establishment of a limit should not be regarded as implying approval of the degradation of a high quality supply to the specified level. The limits described herein have been derived from the best information currently available; however, the development of drinking water objectives is an on-going process. Scientific knowledge of the complex inter-relationships that determine water quality continue to increase as does the understanding of the physiological effects of the substances present in water. Also, man continues to introduce new chemical substances into the environment, many of which may contaminate drinking water supplies. It, therefore, may be necessary to revise the established limits as new and more significant data become available.

1.2 APPLICATION OF LIMITS

A water supply system is defined as including the works and auxiliaries for collection, treatment, storage and distribution of the water from the source of supply to the free-flowing outlet of the ultimate consumer.

The limits outlined in this document apply to all water supply systems which provide water for domestic purposes and serve more than five private residences or are capable of supplying water at a rate greater than 0.5 litres per second.* Although a water supply serving five or fewer private residences is excluded from the application of the limits, it is desirable that the quality of water from these supplies should not be inferior to that supplied to the public in general.

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*OWR Act, R. S. O. 1980
Section 23, Subsection (9)

1.2.1 **Responsibility for Water Quality**

In general, municipalities are responsible for both the inspection of plumbing and the distribution of water. Where there is a Public Utilities Commission that is responsible for the treatment and distribution of water, it acts as a statutory agent for the appropriate municipality, and the municipality therefore remains ultimately responsible for ensuring that a water of adequate quality is delivered to consumers. Re-inspection of plumbing to prevent the occurrence and persistence of cross-connections, and the institution of an adequate sampling program are important functions in fulfilling this responsibility.

Private operators of water supply systems as defined in Section 1.2 are fully responsible for the quality of water delivered to consumers.

1.2.2 **Approval of Water Supplies**

Approval of water supplies shall be dependent in part upon:

(a) Satisfactory quality and adequate quantity of the water source;

(b) Adequate treatment facilities to consistently produce water free of health hazards and to minimize undesirable aspects of finished water quality;

(c) Adequate capacity to meet peak demands without development of low pressures which could result in health hazards;

(d) Enforcement of requirements to prevent development of health hazards;

(e) Records of laboratory analyses showing consistent compliance with the water quality limits stated in these objectives.

1.3 **SOURCE AND PROTECTION**

The water supply should be obtained from a source that is most likely to produce drinking water of a quality meeting the requirements of these objectives. The source chosen should, therefore, be that least subject to pollution by municipal, industrial, and other types of wastewaters and by human activities within the watershed, and every effort should be made to control degradation of this source.

Natural processes such as dilution, storage, sunlight and associated physical and biological processes tend to accomplish some purification in surface waters. In ground waters, natural purification may occur by infiltration of the water through soil, percolation through underlying material, and storage below the water table. Effective treatment should be provided to ensure safety and consistency in the quality of all finished waters.

Treatment could include the controlled processes of coagulation, sedimentation, absorption, filtration and disinfection; in some cases, additional processes may be required to produce a water that consistently meets the requirements of these objectives. The following requirements are necessary: (a) treatment processes that are appropriate for the source of supply; (b) a treatment plant with adequate capacity to meet maximum demands without creating health hazards; (c) a treatment plant designed, located and constructed to minimize the effects of pollution at the raw water intake and to prevent contamination or disruption of the supply during flooding; (d) conscientious, well-trained and competent treatment plant personnel with qualifications commensurate with the responsibilities of the position.

Frequent sanitary surveys of the water source by the purveyor of the water should be carried out. The survey should attempt to recognize all potential sources of pollution of the supply and make an assessment of their present and future importance. The manner and frequency of making these surveys, and any program of problem elimination shall be approved by the Ministry.

2. CHARACTERISTICS RELATED TO HEALTH

The characteristics of water quality that can cause health related effects have been divided into four categories; chemical, physical, microbiological and radioactivity. The maximum acceptable concentration (MAC) for each chemical and physical health related parameter is listed in Table 1, and those for radionuclides in Table 3. The rationales for these limits are discussed in Appendix A. The microbiological limits are listed in section 2.3.2. The presence in a drinking water of

a health related substance in excess of its MAC or limit shall be grounds for its rejection.

2.1 CHEMICAL CHARACTERISTICS – HEALTH

Certain chemicals are toxic and can affect human health. Heavy metals and ions such as cyanide, some commonly occurring organic compounds, and many less common organic and organometallic substances are potentially hazardous in drinking water supplies. Because the intake of these substances from such sources as milk, food, or air may be difficult to avoid, it is desirable to control that fraction of intake associated with drinking water. Maximum acceptable concentrations have been set for those toxic chemical substances that could be present at significant levels in drinking water. In general, the total environmental exposure and the possible adverse effects from long-term exposure to each toxicant has been taken into consideration in deriving its limit.

The aim of setting limits for contamination is to avoid undesirable health effects. However, one chemical species, fluoride ion, is unique in that its presence at carefully controlled concentrations results in a beneficial health effect.

2.2 PHYSICAL CHARACTERISTICS – HEALTH

Colour, odour, taste, temperature and turbidity have traditionally been classified as the physical characteristics of water. Although the direct effects of these parameters are aesthetic, they can have indirect effects on health through interrelationships with health-related parameters. For example, temperature affects the rate of growth of micro-organisms and some colour-producing substances are trihalomethane precursors. At the present time, however, turbidity is the only physical parameter for which there is sufficient data to establish a limit on the basis of health considerations.

2.2.1 Turbidity

Turbidity in water is caused by the presence of suspended matter such as clay, silt, colloidal particles, plankton and other microscopic organisms. Turbidity can serve as a source of nutrients for micro-organisms and interfere with their

enumeration. The adsorptive properties of suspended particles can lead to concentration of heavy metal ions and biocides in turbid waters. Turbidity has also been related to trihalomethane formation in chlorinated water. But the most important health effect of turbidity is its interference with disinfection and with the maintenance of a chlorine residual. Viable coliform bacteria have been detected in waters with turbidities higher than 3.8 even in the presence of free chlorine residuals of up to 0.5 mg/L and after a contact time in excess of 30 minutes, and outbreaks of disease traced to chlorinated water supplies have been associated with high turbidity. To incorporate a safety factor, a maximum acceptable turbidity level of one turbidity unit (1 Formazin turbidity unit – FTU or 1 nephelometric turbidity unit – NTU) has therefore been established.

2.3 MICROBIOLOGICAL CHARACTERISTICS – HEALTH

The microbiological quality of drinking water has traditionally been viewed as the most important aspect of drinking water quality because of its association with waterborne disease. Typhoid fever, cholera, enterovirus disease, bacillary and amoebic dysenteries, and many varieties of gastro-intestinal disease can all be transmitted by water. The introduction of water treatment with disinfection and the implementation of bacteriological surveillance programs to ensure the delivery of safe drinking water have resulted in a dramatic decrease in the incidence of water-related illness. Occasional outbreaks of waterborne disease underline the continuing importance of strict supervision and control over the microbiological quality of drinking water supplies. A more detailed discussion on disinfection can be found in Appendix C.

2.3.1 Bacteriological Indicators

Although modern microbiological techniques have made possible the detection of pathogenic bacteria and viruses in sewage effluents, it is not practical to attempt to isolate them as a routine procedure from samples of drinking water. Pathogens present in water are usually greatly outnumbered by normal intestinal bacteria which are easier to isolate and identify. The presence of the latter organisms in a water sample indicates that pathogens **could** be present; if they are absent, disease-producing organisms are probably also

absent. A more detailed discussion of the various indicator organisms and pathogens is presented in Appendix A.2.

2.3.2 Limits for Distribution Systems

The Most Probable Number (MPN), the Membrane Filter (MF), or the Presence-Absence (P-A) tests may be used to determine coliform and fecal coliform populations for the purpose of assessing drinking water quality. It is noted that the aforementioned methods have varying sensitivities and occasionally when samples are tested in parallel by more than one method, one method will produce positive results whereas the other will not. This may occur more frequently in treated water samples, where stressed or debilitated micro-organisms may be present, which will be recovered only by the most sensitive method. In all cases where discrepancies such as this are found, results from the method producing the positive will be used.

The Presence-Absence test also permits screening for other bacterial indicators of water quality such as discussed in Appendix A.2.1.2. Limits for the various indicator bacteria and the action required if the limits are exceeded are described below. These limits have been divided into two sections in recognition of the fact that indicator organisms may appear as a result of a sudden, serious pollution event; or because of a less serious and gradual deterioration of water treatment or distribution system maintenance practices; or because of accidental contamination of the sample(s); or because of introduced contamination from a cross-connection; or because the sampling tap was insufficiently flushed prior to taking the sample.

2.3.2.1 Unsafe Water Quality – Definition and Corrective Action

Total Coliform bacteria, when determined by the MF or MPN method, should not be present in densities of 5 or more organisms per 100 mL or, when determined by the P-A method, should not give positive results within 48 hours.

Fecal coliforms should not be detected in any sample by any of the methods.

If these limits are exceeded, the water quality is judged unsafe. The regional staff of the Ministry will be notified immediately by telephone by the laboratory for collection of

special samples*. Should the circumstances warrant it, the Medical Officer of Health (MOH) may be contacted by MOE regional staff in the event of results showing a high level of contamination in the system, and corrective action initiated immediately.

Special samples will be collected for analysis from the affected and adjacent locations and simultaneous chlorine residual checks carried out. The operating authority will begin an investigation to determine the probable reason for contamination.

If the results of the **special samples** also exceed the limits, for "Unsafe Water Quality", the MOH will be notified by MOE regional staff and the following further action must be taken.

The chlorine dose will be immediately increased together with flushing to ensure a total residual of at least 1.0 mg/L or a free chlorine residual of 0.2 mg/L to all points in the affected part(s) of the distribution system.

If satisfactory chlorine residuals are not detected in the affected part(s) of the distribution system or if the circumstances warrant, the issuance of a **BOIL WATER** advisory by the Medical Officer of Health may be made. Corrective measures along with intensive resampling and analysis of the entire water system should continue until the limits are no longer exceeded.

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* **Special Samples**
Special sampling shall consist of a minimum of 3 samples to be collected for each positive sample site; one sample should be collected at the affected site, one at an adjacent location on the same distribution line and a third sample should be collected some distance upstream on a feeder line toward the water source. These samples must be marked 'special' on the laboratory submission sheet. The chlorine residual **at the time of sampling** for each site must be marked on the laboratory submission sheet beside each sampling location. The collection of three special samples is considered a **minimum** number for each adverse sampling site. The measurement of the chlorine residuals in the vicinity of the positive sampling sites may assist in the definition of the extent of the contamination within the distribution system, and may be used to determine the appropriate corrective action.

2.3.2.2 **Poor Water Quality – Definition**

a) **Total Coliform and Aeromonas Organisms**

When total coliform bacteria are present at levels below 5 organisms per 100 mL by MF or MPN tests, or when positive P-A results for total coliform bacteria occur after 48 hours incubation, and/or **when Aeromonas organisms are detected they should not occur in more than 25% of the samples of a single submission, nor in successive submissions from the same sampling site.**

Total coliforms at levels below 5 organisms per 100 mL by MF or MPN tests, or producing positive P-A results for total coliform bacteria after 48 hours incubation **should not occur in more than 10% of the samples submitted in any one month. Aeromonas organisms should not occur in more than 15% of the samples submitted in any one month.**

b) **Pseudomonas aeruginosa, Staphylococcus aureus and Members of the Fecal Streptococcus Group**

These organisms should not be detected in any sample.

c) **Standard Plate Counts**

The routine analysis for coliform bacteria should periodically be supplemented by standard plate counts (SPC)*. This should be done by either testing some of the samples from each submission or by testing all the samples in a given submission on a quarterly basis. **The limit for SPC (35°C, 48 hours) is 500 organisms per mL (based on a geometric mean of 5 or more samples).**

When the above limits are exceeded, the Ministry may require more intensive monitoring of the distribution system. The extent of such additional monitoring is at the discretion of the Regional Director of the Ministry of the Environment. An outline of the sampling procedures and corrective measures which could be requested is given in the Appendix (A.2.1.4)

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* Samples for SPC analysis should preferably be kept refrigerated and transported on ice, and be received and analysed within 24 hours of collection.

2.4 RADIOACTIVITY – HEALTH

Man's exposure to radiation results from external sources such as cosmic and terrestrial radiation and internal sources such as radionuclides taken into the body with food, water,

TABLE 3
Guidelines for Radionuclides

Radionuclide*	Maximum Acceptable Concentration** Becquerels/Litre	Target Concentration*** Becquerels/Litre
Cesium-137	50	5.0
Iodine-131	10	1.0
Radium-226	1	0.1
Strontium-90	10	1.0
Tritium	40,000	4,000.0

The above limits refer to the sum of all forms present.

* If two or more radionuclides affecting the same organ or tissue are found to be present, the following relationship based on ICRP Publication 26 should be satisfied:

$$\frac{c_1}{C_1} + \frac{c_2}{C_2} + \ldots\ldots\ldots\ldots \frac{c_i}{C_i} \leq 1$$

where c_1, c_2 and c_i are the observed concentrations, and C_1, C_2 and C_i are the maximum acceptable concentrations for each contributing radionuclide.

** Radionuclide concentrations exceeding the maximum acceptable concentrations may be tolerated provided that the duration of the increase is short and that the annual average concentrations remain below this level and meet the restriction for multiple radionuclides.

*** **The target concentration is intended to be a guideline for life-long continuous consumption.** Radionuclide concentrations exceeding this level on a continuous basis are acceptable provided the situation is reviewed by the health authorities, taking into account factors such as magnitude and duration of population exposure.

inhaled air and particulate matter. With respect to internal sources, the important factors to be considered from the health viewpoint are the radiation doses delivered to the organs and tissues of the body resulting from intakes of radionuclides. The radionuclides currently of greatest interest from a health viewpoint are tritium, strontium-90, iodine-131, cesium-137, and radium-226. The guidelines for these radionuclides are set out in Table 3.

The guidelines for the radiological characteristics of water are based on dose-response relationships as recommended by the International Commission on Radiological Protection (ICRP) in publication 26. Maximum acceptable concentrations in drinking water have been derived which correspond to one per cent of the ICRP recommended annual occupational dose equivalent limits for continuous exposure. Target concentrations have been derived which correspond to one tenth the maximum acceptable concentration. The guidelines can be calculated using ICRP recommended annual limits of intake in publication 30. An average daily intake of 2 litres of drinking water is assumed.

3. CHARACTERISTICS RELATED TO AESTHETIC AND OTHER CONSIDERATIONS

The water quality characteristics discussed in this section do not directly affect the safety of a water supply but may cause aesthetically objectionable effects or render a water unsuitable for use as a piped supply. The primary goal in setting limits on the basis of aesthetic considerations is to produce a treated water that pleases consumers. Compliance with these limits could result in associated health benefits. Pleasing aesthetic qualities will discourage the use of alternative water sources which may produce aesthetically pleasing water but which have poor quality control in respect of health-related parameters.

Maximum desirable concentrations have been derived for a number of chemical and physical characteristics that affect the aesthetic quality of drinking water or interfere with good water quality control practices. These limits are listed in Table 2. The criteria used in deriving these values are discussed in Appendix B. A maximum desirable concentration should not be exceeded when more suitable supplies are, or can be made available at a reasonable cost.

3.1 CHEMICAL CHARACTERISTICS - AESTHETIC

The chemical substances discussed in this section may be aesthetically objectionable, interfere with water treatment processes and distribution, or stain fixtures and plumbing.

3.2 PHYSICAL CHARACTERISTICS - AESTHETIC

The physical characteristics provide what is probably the oldest method of judging water quality, and the acceptability of drinking water to consumers still depends to a large degree on apparent colour, clarity, taste, odour and temperature. Certain of the physical characteristics may also interfere with treatment processes and the economic functioning of the water supply system.

An important feature of each physical characteristic is its relationship with other water quality parameters. For example, colour may be related to the presence of iron or manganese; taste and odour perception are affected by temperature; and pH is intimately related to corrosion and incrustation which, in turn, can affect apparent colour, taste and odour. Thus, control of a given physical characteristic can result in improvements of other aspects of drinking water quality.

3.3 BIOLOGICAL CHARACTERISTICS - AESTHETIC

Biological organisms that may cause problems in water supplies include several species of algae, protozoa and other organisms that may produce unpleasant tastes and/or clog filters; iron bacteria that cause discolouration, turbidity and taste problems and form slime and iron oxide accumulations in pipes, reducing the capacity of the system; sulphate-reducing bacteria that contribute to corrosion of water mains and to taste and odour problems; and nematodes and possibly other macro-organisms which do not themselves pose a direct health risk, but which may harbour pathogenic viruses and bacteria and prevent their exposure to chlorine.

Biological examination of drinking water is of greatest value in determining the cause of objectionable tastes and odours and clogging in distribution pipes and filters. These problems are more likely to occur in supplies where conventional flocculation and filtration processes are not used; most of these organisms are removed by conventional water treatment processes. Nuisance organisms are particularly diffi-

cult to control once they become established within the distribution system. Many are resistant to the disinfecting action of chlorine or are protected by debris and slime. It is difficult however, to specify any quantitative limit on these organisms because individual species differ widely in their ability to produce undesirable effects. Many of the problems caused by nuisance organisms are covered by the limits on the physical characteristics of water (Appendix B.3).

The population of organisms within a water supply system can be largely controlled by reducing the nutrients entering the system, eliminating the entry of invertebrates, and keeping the distribution system clean. This can be achieved by efficient treatment, which allows only low turbidity water to enter the system, covering reservoirs, maintaining a chlorine residual, systematic cleaning of the distribution system by flushing and foam swabbing, and the application of good practices when repairing or replacing old mains or preparing new mains for service.

4. SAMPLING AND EXAMINATION

Samples are taken from water supply systems primarily to determine whether the water supplied is safe for human consumption and they must, therefore, be representative of the supply as a whole. If the sample is carelessly collected or is taken from locations that are not representative of the whole system, then the purpose of sampling is defeated. Unrepresentative sampling may even be dangerous because it can give rise to unjustified confidence in the quality of water. It **may also cause unnecessary cost and concern.** The health significance of a parameter, the degree to which its concentration varies over time, other factors that may affect it and the population at risk should be considered in determining the sampling frequency.

It is important to note that a single sample is of limited value; the most a single sample can show is the water quality at the time of examination. Therefore, it is necessary that repeated samplings be performed and complete records be maintained in order to get an adequate picture of the conditions in the water supply. The use of recognized standard analytical techniques also facilitates the comparison of data collected in different places at various times and thus the identification of trends in water quality. The availability of reliable, up-to-

date, comprehensive information on contaminants to which the public may be exposed is essential for establishing new limits or updating old ones.

The methods used for determining the characteristics shall be as prescribed in the current edition of the **Outlines of Analytical Methods** published by the Laboratory Services and Applied Research Branch, Ministry of the Environment. Where such methods are not suitable because of scale or equipment limitations, the methods used shall be as prescribed in the current edition of **Standard Methods for the Examination of Water and Wastewater.***

4.1 CHEMICAL EXAMINATION

Examination of drinking water for chemical characteristics is not generally required as frequently as that for bacteriological control. The minimum standards for frequency and location of sampling shall be as determined by the Ministry. To establish a data base, analyses need be made only annually on a sample of the treated water at the water plant and at a selected point(s) in the distribution system.

It should be borne in mind that the chemical quality of a supply may change seasonally or in response to weather conditions and agricultural practices etc., and in these cases sampling should be such as to provide adequate supervision of water quality to ensure that the health of the consumer is not being endangered.

If the results of analyses indicate that the level of any contaminant exceeds the maximum acceptable concentration three additional analyses of samples from the same sampling point shall be done within a month. If the average of the four analyses exceeds the maximum acceptable concentration, monitoring at a frequency designated by the Ministry shall continue until the maximum acceptable concentration has not been exceeded in two successive samples or corrective action has been successful in eliminating the problem.

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* American Public Health Association/American Water Works Association/Water Pollution Control Federation, available from APHA, Washington.

Where the concentration of a substance is not expected to increase in processing and distribution, available and acceptable source-water data may be used as evidence of compliance with these objectives. Where experience and data indicate that particular substances are consistently absent from a water supply or below levels of concern, less frequent examinations for those substances may be approved by the Ministry.

4.1.1 Fluoride

Where fluoridation is practised, the fluoride concentration recommended is 1.2 mg/L and deviation from this optimum should not exceed ±0.2 mg/L. Daily analyses of samples from the plant effluent and selected points in the distribution system should be done to ensure that the desired concentration is maintained. The amount of fluoride added each day and the amount of water to which it was added should be used to calculate the average dosage of fluoride as a check against the analyses results. Defluoridated supplies should be sampled and analysed at least daily to ensure the maximum acceptable concentration is not exceeded.

4.2 PHYSICAL EXAMINATION

The minimum standards for frequency and manner of sampling shall be as determined by the Ministry. Under normal circumstances, samples should be collected one or more times per week from representative points in the distribution system and examined for colour and taste.

For all surface supplies and those ground water supplies which are being disinfected because of bacteriological quality, at least one turbidity determination should be done daily at the point where the water enters the distribution system. It is desirable that turbidity should be continuously monitored and recorded.

Most of the parameters set forth in these objectives may be analysed in the laboratory, while a few are best determined in the field. Details concerning the proper collection, preservation and shipment of samples, plus a listing of the analytical capabilities of the various regional Ministry Laboratories are contained in the publication "A Guide to the Collection and Submission of Samples for Laboratory Analysis". Copies may be obtained through the Water Quality Section, Laboratory

Services and Applied Research Branch, P.O. Box 213, 125 Resources Road, Rexdale, Ontario M9W 5L1.

4.3 BACTERIOLOGICAL EXAMINATION

Contamination by sewage or excrement presents the greatest danger to public health associated with drinking water, and bacteriological testing provides the most sensitive means for the detection of such pollution.

Every water supply should be regularly inspected from source to distribution taps, and sampling should be repeated under various seasonal conditions and especially after heavy rainfalls. Contamination is often intermittent and may not be revealed by the examination of a single sample. Therefore, if a sanitary inspection shows a water as distributed, to be subject to pollution, the water should be considered suspect irrespective of the results of bacteriological analyses of water leaving the treatment plant.

4.3.1 Sample Collection

A minimum sample volume of 100 mL is required for the bacteriological analyses of drinking water, however, when the P-A procedure is employed a volume of at least 160 mL is preferred as this volume will permit both P-A, and MF or MPN analyses when required.

Sterile bottles, containing sodium thiosulphate must be used to collect samples for submission to a Ministry laboratory for bacteriological analysis. To ensure reliable results, samples should arrive at the testing laboratory within 24 hours of sampling or be refrigerated if delay is unavoidable. Samples older than 72 hours, or collected in containers presumed unsterile, or held under unsatisfactory storage conditions will be discarded and new samples requested.

Bacteriological sample bottles should be stored in a manner to minimize dust accumulation on the external surface of the bottles, as this may contribute to false positive bacteriological results. Sample bottles which appear dusty or unclean should be returned to the laboratory without being used.

4.3.2 Frequency and Location of Sampling

The frequency and location of collection of bacteriological samples from a water supply system should be such as to

maintain a proper supervision of its bacteriological quality. The frequency of analyses and the location of sampling points shall be established by the Ministry after investigation of the source, method of treatment, and protection of the water concerned. The samples shall not necessarily be taken from the same points on each occasion.

4.3.2.1 Treatment Plant Samples

In systems utilizing surface water or treated ground water, samples shall be taken from the raw water source and the point at which the treated water enters the distribution system, at least weekly in systems serving populations up to 100,000 and more often in larger systems. In addition, the operator must ensure that the chemical disinfection process is functioning properly at all times. In systems utilizing untreated ground water, samples shall be taken and examined not less than once per week from the source and all points at which water enters the distribution system.

4.3.2.2 Distribution System Samples

The minimum number of bacteriological samples to be collected and the frequency of sample collection from a distribution system shall be determined from the following table:

TABLE 4
Distribution System Sampling Requirements

Population Served	Minimum Number of Samples per Month	Minimum Frequency Sampling
Up to 100,000	8 + 1 per 1,000 population	Weekly
Over 100,000	100 + 1 per 10,000 population	Several times per week

When a municipality or other operating authority begins experiencing adverse water quality from any of its sampling

sites according to the "Limits for Distribution Systems", the sampling program should be carried out as outlined in Section 2.3.2 or Appendix A2.1.4. These samples shall be considered additional to the total number required to be collected by a municipality.

Samples must be analysed by methods and laboratories acceptable to the Ministry and the results must be assembled and available for inspection by the Ministry.

4.4 RADIOLOGICAL EXAMINATION

The analysis frequency is to be dependent on the concentration of a radionuclide in the water supply, the higher the concentration the more frequent the analysis.

Most radionuclides can be measured directly or can be expressed in terms of surrogate measurements such as gross alpha emission (e.g. radium-226) and gross beta emission (e.g. strontium-90, iodine-131, cesium-137). Tritium is not included in either surrogate and must be measured separately.

The gross alpha and gross beta determinations are only suitable for preliminary screening procedures; compliance with the objectives may be inferred if these are less than the most stringent target concentrations. When these levels are exceeded, analysis for the specific radionuclides must be carried out.

Where public water supplies are taken from sources subject to discharges of radioactive waste, the sampling frequency for certain radionuclides should be increased as recommended by the Ministry of the Environment.

Action on Analyses Results

If the target concentration (0.1 MAC) is not exceeded, then analysis need only be made annually.*

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* It is recommended that the sampling frequency should be greater than the minimum analysis frequency and that samples should be composited. Details of sampling procedures and required preservation methods may be obtained from the Ministry of Labour, Radiation Protection Laboratory.

If the target concentration is exceeded, analyses should be made quarterly. When two consecutive analyses are below the target concentration, annual analysis will suffice.

If the MAC is exceeded the water will be immediately resampled, analysed and the appropriate action taken as determined by the Ministry of the Environment.

APPENDIX A

SUMMARY STATEMENTS – PARAMETERS RELATED TO HEALTH

A.1 CHEMICAL PARAMETERS – HEALTH

A.1.1 Fluoride

The presence of small amounts of fluoride in drinking water leads to a substantial reduction in the incidence of dental caries, particularly among children. Where fluoridation (supplementation of fluoride in drinking water) is practised, the fluoride concentration recommended is 1.2 mg/L.

Excessive fluoride intake produces dental fluorosis, a condition characterized by mottling of tooth enamel. The maximum acceptable concentration for naturally occurring fluoride is 2.4 mg/L.

A.1.2 Inorganic Substances

Maximum acceptable concentrations for the inorganic substances of concern are listed in Table 1. The criteria used in setting these limits are described briefly below. In addition, there are short discussions on sodium and asbestos, both of which may be significant from a health viewpoint but for which no limits have been specified.

A.1.2.1 Arsenic

The toxicity of arsenic is well known. Except in areas close to natural, agricultural, or industrial sources of arsenic contamination, arsenic is present at very low concentrations in surface waters. A number of disorders have been associated with the intake of arsenic in drinking water, but the lowest concentration at which symptoms develop has not been clearly established. There is, however, no evidence of any illness associated with the ingestion of water containing arsenic at the maximum acceptable concentration, 0.05 mg/L. Some studies have suggested that arsenic is either a carcinogen or co-carcinogen, and it is therefore advisable that the level of arsenic in drinking water be as low as possible.

A.1.2.2 Asbestos

Asbestos is a general term applied to certain minerals that form soft, flexible fibers in metamorphic rocks. It may be

introduced into natural waters by the dissolution of asbestos-containing rocks and from industrial sources. The use of asbestos-cement (A-C) pipe in the distribution system of water supplies may contribute to the asbestos content of drinking water if the aggressiveness of the water is not under control. However, aggressive waters can be easily made non-aggressive with simple treatment modification. There is a lack of reliable historical data on levels of asbestos in water, because of the unavailability until recently of a standardized method for asbestos determinations. Background levels as determined by the "Ministry of the Environment Method" in use since 1977, indicate levels in Ontario surface and ground water generally at or below the detection limit of the method. Optimized conventional water treatment practices (coagulation-flocculation and filtration) are considered effective in the reduction of asbestos in potable water. The health hazards associated with occupational exposure to airborne asbestos have been well documented, but similar evidence of a health risk associated with ingestion of asbestos has not been found. The absence of a reliable historical data base for asbestos in water, precludes an epidemiological assessment of human health effects from ingested asbestos; hence, a maximum acceptable concentration for asbestos cannot be reasonably established at this time. However, prudence would suggest keeping asbestos levels in drinking water as low as possible.

A1.2.3 **Barium**

Barium is a relatively common constituent of the earth's crust, but in aquatic systems, it is seldom present at concentrations greater than 1 mg/L. Ingestion of barium can result in serious physiological effects. In man, a single dose of 125 mg/Kg of soluble barium can elicit an acute toxic response. At very low levels, the toxicological effects of barium are not as well understood. The maximum acceptable concentration, 1.0 mg/L, is considered adequate to provide a satisfactory factor for safety.

A1.2.4 **Boron**

The most likely boron species in water is boric acid. In humans, a number of acute boron poisonings have resulted from the use of borates as antiseptic agents and from accidental ingestion, but the levels of exposure were much

higher than would be encountered in drinking water. Infants, the elderly, and individuals with kidney diseases are the groups most susceptible to the toxic effects of boron compounds. The maximum acceptable concentration, 5.0 mg/L, is considered to provide a sufficient safety factor from boron intoxication. Drinking water supplies generally have boron concentrations of less than 1 mg/L.

A1.2.5 **Cadmium**

Cadmium is a highly toxic element. Water can be contaminated with cadmium from natural or industrial sources. Cadmium compounds used in plumbing materials may also be a significant source of contamination of drinking water during distribution. For non-occupationally exposed individuals, food is the main source of cadmium intake. A provisional tolerable weekly cadmium intake for an adult has been estimated by a joint FAO/WHO* expert committee to be from 0.4 to 0.5 mg. Since it would be difficult to reduce cadmium intake from food, intake from water should be as low as possible. Daily consumption of two litres of water containing the maximum acceptable concentration of cadmium, 0.005 mg/L, would result in the ingestion of only about 15 per cent of the tolerable intake.

A1.2.6 **Chromium**

Trivalent chromium, the most common naturally occurring state of chromium is not considered to be toxic. However, if present in raw water, it may oxidize to hexavalent chromium during chlorination. Known harmful effects of chromium in man are attributed primarily to this hexavalent form. Drinking water containing chromium at the maximum acceptable concentration, 0.05 mg/L, has not resulted in any known harmful effects to the health of man or animals.

A1.2.7 **Cyanide**

Cyanides are widely used in industry, and industrial effluents are the major sources of the cyanide contamination of water. Cyanide at doses of less than 10 mg is readily detoxified to thiocyanate in the body. The lethal toxic effects of cyanide

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* Food and Agricultural Organization/World Health Organization.

usually occur only when this detoxification mechanism is overwhelmed. The maximum acceptable concentration for free cyanide, 0.2 mg/L, therefore provides a safety factor of approximately 25. Adequate chlorination for cyanide oxidation will reduce cyanide to a level below this limit.

A1.2.8 **Lead**

Ingestion of lead can result in serious illness or death. Lead is a cumulative poison, and long-term ingestions of relatively low levels can be injurious to health. The minimum dose at which adverse human health effects occur as a result of chronic exposure has not been precisely established. There is, however, no evidence of any illness associated with the ingestion of drinking water containing lead at the maximum acceptable concentration, 0.05 mg/L. A significant source of lead in municipal drinking waters, particularly in soft or aggressive water areas, may be old lead service connections.

A1.2.9 **Mercury**

Mercury is a toxic element and serves no known beneficial physiological function in man: alkyl compounds of mercury are the most toxic to man, producing illness, irreversible neurological damage, or death from the ingestion of milligram quantities. Food is the major source of human exposure to mercury, and fish, which bioconcentrate organic mercury in their tissues, are the most important food source of mercury. Long-term daily ingestion of approximately 0.25 mg of mercury as methyl mercury has caused the onset of neurological symptoms. The maximum acceptable concentration for mercury in drinking water, 0.001 mg/L, provides a considerable margin of safety. Mercury levels in both source water and tap water are generally well below this level.

A1.2.10 **Nitrate**

The maximum acceptable concentration of nitrates in drinking water, 10 mg/L as N, is based on consideration of the relationship between infantile methemoglobinemia and the presence of nitrate in drinking water. The nitrate ion is not directly responsible for this disease but must first be reduced to nitrite ion by intestinal bacteria. The nitrite ion reacts with the iron of hemoglobin to produce an altered hemoglobin, methemoglobin, which is unable to transfer oxygen and thus

the tissues become oxygen-starved. Therefore the occurrence of nitrate ion in water commands caution.

Nitrate poisoning from drinking water appears to be restricted to susceptible infants; older children and adults drinking the same water are unaffected. Most water-related cases of methemoglobinemia have been associated with the use of water containing more than 10 mg/L nitrate as N or 45 mg/L nitrate. In Canada, no cases of this disease have been reported where nitrate concentration was consistently less than the maximum acceptable concentration. Where both nitrate and nitrite are present, the total nitrate plus nitrite-nitrogen concentration should not exceed 10 mg/L. In areas where the nitrate content of water is known to exceed the maximum acceptable concentration, the public should be informed by the appropriate health authority of the potential dangers of using the water for infant feeding.

A1.2.11 **Nitrite**

The maximum acceptable concentration of nitrite in drinking water, 1.0 mg/L as N, is based, as with nitrate, on the relationship between nitrite in water and the incidence of infantile methemoglobinemia. Nitrite is quickly oxidized to nitrate and is therefore seldom present in surface waters in significant concentrations. Nitrite may occur in ground water sources, however, if chlorination is practised, it will be oxidized to nitrate. The contribution of nitrite from drinking water to the total daily intake would be negligible for most public water supplies.

A1.2.12 **Selenium**

The symptoms of selenium intoxication in man are rather ill-defined. Also, it is difficult to establish levels of selenium that can be considered toxic because of the complex inter-relationships between selenium and dietary constituents such as protein, vitamin E, and other trace elements. Food is the main source of selenium intake for non-occupationally exposed individuals. Drinking water containing selenium at the maximum acceptable concentration, 0.01 mg/L, would be the source of only 10 per cent of total selenium intake; the maximum acceptable concentration is therefore considered to provide a satisfactory factor of safety from known adverse effects.

A1.2.13 Silver

Concentrations of silver in water are generally very low. Elevated levels of silver in drinking water can arise however, from the use of silver as a water disinfectant. Ingestion of excessive amounts of silver may result in argyria, a condition characterized by a blue-grey discolouration of the skin, eyes, and mucous membranes. The exact quantity of silver required to produce argyria is unknown, but it is believed to be in the order of 1,000 mg. The maximum acceptable concentration, 0.05 mg/L, therefore incorporates a substantial margin of safety.

A1.2.14 Sodium

Sodium is not considered to be a toxic metal, and in excess of 10 grams per day is consumed by normal adults without apparent adverse effect. In addition, the average intake of sodium from water is only a small fraction of that consumed in a normal diet. A maximum acceptable concentration for sodium in drinking water has therefore not been specified. Persons suffering from hypertension or congestive heart failure may require a sodium-restricted diet in which case the intake of sodium from drinking water could become significant. It is therefore recommended that the measurement of sodium levels be included in routine monitoring programs of water supplies. The Medical Officer of Health should be notified when the sodium concentration exceeds 20 mg/L, so that this information may be disseminated to local physicians.

A1.2.15 Uranium

Uranium is normally present in biological systems and aqueous media as the uranyl ion (UO_2^{2+}). Ingestion of large quantities of uranyl ion may result in damage to the kidneys. The uranyl ion may also be responsible for objectionable taste and colour in water, but the concentrations at which this happens are much higher than the concentrations which may cause kidney damage.

The existing data are insufficient to permit establishment of a maximum acceptable concentration for uranium in drinking water. The available information does suggest that water containing 0.02 mg/L uranium would not pose a health risk. Therefore an interim limit of 0.02 mg/L is being

recommended. This value is considered to be ultra-conservative and should be used with discretion and if exceeded should signal the need for more sampling to establish possible fluctuations of uranium concentrations and radionuclide activity in the drinking water.

A1.3 **Organic Substances**

Organic chemical substances are present to some degree in all municipal water supplies. The sources of these chemicals are diverse. Industrial and municipal waste, urban and rural runoff, and the natural decomposition of biological matter may all contribute to the organic content of water. The organic chemical contaminants of drinking water may be divided into two classes on the basis of origin: natural or synthetic.

The major portion of organics in most waters is of natural origin. These natural substances consist primarily of undefined or poorly defined humic and fulvic materials and other products of organic decomposition. The constituents have presumably always been present in drinking water and are not in themselves likely to present a health hazard. Maximum acceptable concentrations have therefore not been set for any naturally occurring organic chemicals.

Synthetic organic chemicals in drinking water can be the result of certain water treatment practices or the direct contamination of the raw water from point and non-point sources of pollution. Normally the contribution of the synthetic component to the total organics content is small, but it may be significant in highly polluted waters. Most synthetic organic chemicals that have been detected in water are present at such low concentrations that they appear to pose no substantial additional threat to human health. However, the majority of synthetic organic chemicals that have been identified in drinking water have not been examined exhaustively for potential health effects; as a matter of prudence the concentrations of such materials should therefore be as low as possible.

Maximum acceptable concentrations have been set only for a few of those organic chemicals that could conceivably be present in drinking water at levels that pose a human health hazard.

A1.3.1 **Nitrilotriacetic Acid**

Nitrilotriacetic acid (NTA) has many industrial applications but its main use is as a "builder" in laundry detergents. Most of the NTA used is therefore eventually disposed of in domestic sewage, and it is consequently a potential contaminant of drinking water supplies. In general, the toxicity of NTA is very low, however, an increased incidence of urinary tract tumours was found in rats and mice that had been fed very large doses of NTA. Risk assessment using these data, together with the relatively poor absorption of NTA by man, suggests that the risk associated with a NTA level in drinking water of 0.05 mg/L is negligible.

A.1.3.2 **Pesticides**

Three groups of pesticides are important in water quality evaluation: chlorinated hydrocarbons and their derivatives; chlorophenoxy herbicides; and the cholinesterase-inhibiting compounds that include the organo-phosphorus chemicals and carbamates. Chlorinated hydrocarbon compounds tend to persist in the environment. Some cause either direct health effects or indirect effects due to biological concentration in man's food chain. Organo-phosphorus compounds and the cholinergic carbamates, although they may have high acute toxicity to mammals, hydrolyse rapidly in the aquatic environment to harmless or less-harmful products. As a matter of prudence it is desirable that drinking water be free of pesticides, and every effort should be made to prevent pesticide pollution of raw water sources.

Maximum acceptable concentrations have been derived for those pesticides for which acceptable daily intake (A.D.I.) values have been published by the World Health Organization or the U.S. Environmental Protection Agency. Daily consumption of two litres of water containing the maximum acceptable concentration of a specific pesticide, would result in the ingestion of not more than 20 per cent of A.D.I. for that pesticide. It is recognized that the list of pesticides in Table 1 is not comprehensive and constitutes only a small fraction of such substances available in Ontario. Local circumstances may require the use of a pesticide for which guidelines have not been established. Monitoring for the presence of such substances in drinking water may, therefore, be deemed desirable. When a pesticide not listed

in Table 1, is detected in a water supply, advice should be obtained from the appropriate health authority.

A.1.3.3 **Polychlorinated Biphenyls**

Polychlorinated biphenyls (PCBs) are among the most ubiquitous and persistent pollutants in the global ecosystem. In the past, PCBs have been marketed extensively for a wide variety of purposes but their use in Canada is currently being phased out. There is some evidence which suggests that PCBs may be carcinogenic, however, the data are insufficient to permit establishment of a maximum acceptable concentration of PCBs in drinking water. The available information does suggest that drinking water containing PCB's at a concentration of 0.003 mg/L would not pose a health risk. Therefore, an interim limit of 0.003 mg/L is recommended. Alternative supplies of drinking water should be considered if this limit is exceeded.

A.1.3.4 **Trihalomethanes**

The trihalomethanes are the most widely occurring synthetic organics found in drinking water, and they also appear at the highest concentrations. Four trihalomethanes have been detected in drinking water: chloroform, bromodichloromethane, chlorodibromomethane, and bromoform. The principal source of trihalomethanes in drinking water is the chemical interaction of chlorine added for disinfection, with humic and fulvic substances that occur naturally in the raw water. It has been demonstrated in rodents that the ingestion of large doses of chloroform results in the development of malignant tumours. There is some evidence that the other trihalomethanes are also carcinogenic. Risk assessment using data from the rodent studies suggests that low doses of chloroform may produce some incidence of cancer in man. Based on a very conservative statistical model, at a maximum acceptable concentration of 0.35 mg/L, the health hazard to man posed by the presence of trihalomethanes is considered negligible. Trihalomethane levels in surveyed public water supplies are generally well below this concentration.

A2 MICROBIOLOGICAL PARAMETERS – HEALTH

A2.1 Bacteria

A2.1.1 Coliform Organisms

The coliform group of micro-organisms has been the most commonly used bacteriological indicator of water quality. The group includes all Gram-negative, asporogenous, cytochrome-oxidase negative, catalase positive, rod-shaped bacteria capable of growing in a bile-salt medium and of fermenting lactose within 48 hours when incubated at 35 to 37° C. The group generally comprises the genera **Escherichia, Klebsiella, Enterobacter** and **Citrobacter**. The fecal coliform group includes that portion of the coliform group that is capable of growth at 44 to 45° C within 24 hours. The genus most frequently associated with recent fecal pollution is **Escherichia.**

Because of its specificity for fecal contamination, the fecal coliform measurement is preferred for monitoring raw water quality and to indicate the potential presence of pathogens at source. In contrast, some strains included in the total coliform group are widely distributed in the environment but are less common in fecal material. These organisms tend to survive longer in water and are more resistant to chlorination than either the fecal coliforms or the commonly occurring bacterial pathogens. The total coliform group is, therefore, preferred as an indicator of treatment adequacy in drinking water supply systems. It is reasonably certain that organisms which may cause intestinal disturbances are absent from water if coliform bacteria are not found during the examination of 100 mL samples.

A2.1.2 Other Indicators of Bacteriological Quality

Several genera of bacteria are indicative of poor water quality; these organisms can be detected by the P-A test. The fecal streptococcus group comprises a number of species of the genus **Streptococcus** which by cultural and serological methods fall into the Lancefield's Group D category. These bacteria are Gram-positive cocci, catalase negative, and capable of growth at 45° C within 48 hours; not all are associated with fecal contamination but those species that are, include **S. fecalis**, **S. fecium**, **S. durans, S. bovis** and **S. equinus.**

Pseudomonas aeruginosa and **Staphylococcus aureus** are occasionally isolated from distribution system samples. Both of these organisms, which are found in sewage, are potentially pathogenic and should be absent from domestic drinking water supplies.

Aeromonas is a Gram-negative, asporogenous, cytochrome-oxidase positive, rod-shaped bacterium which frequently gives false positive coliform reactions. Its association with polluted water and sewage makes its presence in water supplies undesirable.

A2.1.3 **General Bacterial Population**

There are many micro-organisms commonly present in treated drinking water whose numbers far exceed those of the coliform group.

The method used for determining a standard plate count (SPC) of this general population shall be as prescribed in the current edition of the **Handbook of Analytical Methods for Environmental Samples**. Where such methods are not suitable because of scale or equipment limitations, the methods used shall be as prescribed in the current edition of **Standard Methods for the Examination of Water and Wastewater.**

These counts can be used for quality control in water treatment plants and as a measure of quality deterioration in distribution lines and reservoirs.

A2.1.4 **Suggested Sampling Procedures and Corrective Measures for Poor Water Quality**

a) **Total Coliform & Aeromonas Organisms**

i) When the limits are exceeded from a single sample submission, **repeat samples** may be requested from the sites yielding the positive results along with simultaneous determination of the chlorine residuals. (These **repeat samples** should be so marked on the submission sheet along with the chlorine residual result).

If any of the repeat samples show the presence of any of the indicators of poor water quality, the regional staff of the Ministry should be notified by telephone and **special samples**, (see Page 11) should be collected at the positive locations.

If the results of the **special samples** are also positive for poor water quality indicators, corrective action may be indicated, such as, instituting chlorination, increasing chlorine dosage, flushing and, if necessary, foam swabbing.

ii) When the limits are exceeded in successive submissions from the same sampling site, then the regional staff of the Ministry should be notified by telephone by laboratory staff and **special samples** should be collected. If the limits are again exceeded corrective action should be carried out as under i) above.

iii) When the limits are only exceeded for the monthly sample totals, the operating authority should undertake a review of distribution system maintenance procedures, chlorine residuals and plant operations.

b) **Pseudomonas aeruginosa, Staphylococus aureus and Members of the Fecal Streptococcus Group**

When positive samples are found **repeat samples** may be requested from the affected sites along with the simultaneous determination of chlorine residuals.

If any of the repeat samples are positive, the regional staff of the Ministry should be notified by telephone and **special samples** should be collected. If these samples are also positive, the appropriate corrective action, as outlined in a) i) may be indicated.

c) **Standard Plate Counts**

If this limit is exceeded **repeat samples** may be requested. If the limit is exceeded in the repeat sampling, the regional staff of the Ministry should be notified by Laboratory staff by telephone and corrective action carried out as in a) i).

A2.2 **Viruses**

Viruses are ultramicroscopic intracellular parasites, incapable of growth outside living cells under ordinary circumstances. Of importance in water are those viruses shed in fecal material, the enteric viruses. These viruses include polioviruses, coxsackie viruses, echoviruses, adenoviruses, reoviruses, and the viruses of hepatitis and gastroenteritis. Altogether more than 100 different antigenic types are recognized. Since none of the generally accepted sewage treatment methods yield virus-free effluent, some of this virus is discharged into surface waters. In addition, the

disposal of domestic wastewater effluents and solids on land can lead to the viral pollution of ground water. Thus, both ground and surface waters that are used as a drinking water source may contain virus.

All water treatment processes remove or destroy viruses to a certain degree, but disinfection is the only reliable process by which water can be made free of virus. Both chlorine and ozone can, under the proper conditions, be effective virucides. In general, at a pH below 8.0 a turbidity less than 1 FTU and a temperature above 4° C, maintenance of a **free** chlorine residual of 0.5 mg/L for 30 minutes should provide virus-free water. The limited literature on ozone suggests that with respect to viruses, it is a superior disinfectant to chlorine.

It should be stressed, however, that most enteric viruses have not been tested to determine their chlorine or ozone resistance. The available information does suggest that a well-managed water treatment system providing effective disinfection and using a free chlorine residual will produce safe water. Overt outbreaks of disease from properly treated supplies are not known to have occurred.

Although virus detection methodology has improved greatly in recent years, no virus limit can be proposed at this time. Analytical procedures have been tested with only a small number of the over 100 virus types that may be present in water, and hepatitis virus and the gastroenteritis viruses, which are probably the most important from a health viewpoint, cannot even be tested because of the lack of suitable tissue cultures for their quantification. The available analytical techniques are complex and expensive and restrict the virological examination of water to well-equipped laboratories with highly trained personnel.

A2.3 **Protozoa**

Man is the natural host of a number of parasitic animals. With respect to drinking water, most important are the protozoan parasites **Entamoeba histolytica**, which causes amoebic dysentery and hepatitis, and **Giardia lamblia**, which can be responsible for gastrointestinal disturbances, flatulence, diarrhea, and discomfort. The recent occurrence of large community outbreaks of giardiasis has increased the interest in the waterborne transmission of this disease, but assessment of the public health significance of **Giardia** in

water supplies has been hampered by the unavailability of simple, reliable techniques for the detection, identification, and enumeration of these organisms. Protozoan cysts are not destroyed by usual chlorination practices; however cysts will be removed by sedimentation and filtration processes. The greatest risks from waterborne protozoan infections are associated with water systems that use only disinfection and with contamination of water in the distribution system by sewage from broken lines or cross-connections. Adequate treatment of the raw water and proper maintenance of the water supply system appear to provide the best protection against these organisms.

A3 RADIOLOGICAL PARAMETERS – HEALTH

There are more than 200 radionuclides, some of which occur naturally and others which originate from activities of man such as nuclear energy production, nuclear weapons testing, manufacture and use of radioisotopes, processes that use naturally occurring radionuclides for their chemical as opposed to radiological properties and processes that use raw products which are contaminated with naturally-occurring radionuclides in concentrations greater than are generally found in soil or processes which inadvertently concentrate naturally occurring radionuclides. As mentioned in Section 2.4 the radionuclides currently of greater interest from a health view-point are tritium, strontium-90, iodine-131, cesium-137 and radium-226. Of these, tritium and radium-226 are naturally occurring, but their levels may be enhanced above background due to operations associated with the nuclear fuel cycle. Tritium is introduced by its release from nuclear-power generating facilities; radium-226 levels may be elevated in water bodies that drain areas in which uranium mining and milling are conducted.

Ingestion of radionuclides in drinking water may cause cancer in exposed individuals and genetic changes in their progeny. The probability of inducing such effects is assumed to be proportional to the radiation doses delivered to sensitive organs and tissues. It is assumed that no threshold exists below which the probability of induced effects is zero.

For practical purposes it is necessary to select numerical guidelines for radionuclide concentrations in water to protect consumers of drinking water from unacceptable risks (MAC).

When further steps might be taken to achieve an even lower level, this lower level (Target Concentration) should not be set so stringently that most of the water supplies in the Province are deemed to be unacceptable by reason of the naturally occurring levels of naturally occurring radionuclides.

Accordingly, in keeping with the philosophy of the ICRP, levels should be as low as is reasonable achievable, economic and social considerations being taken into account.

With these principles in mind, two guidelines for radionuclide concentrations have been adopted by the Province.

APPENDIX B

SUMMARY STATEMENTS - PARAMETERS RELATED TO AESTHETIC AND OTHER CONSIDERATIONS

B.1 INORGANIC CHEMICAL PARAMETERS - AESTHETIC

The criteria used in deriving the maximum desirable concentrations for eight inorganic chemical species are outlined below. Also, four non-specific inorganic parameters are discussed.

B.1.1 Alkalinity

A limit on alkalinity may be necessary to ensure that it is sufficient to enable optimum floc formation during coagulation processes, but not so high as to cause gastrointestinal discomfort or irritation and that it affords a proper chemical balance so that the water is neither corrosive nor incrusting. Generally, in water analysis, alkalinity is expressed in terms of equivalent amount of calcium carbonate. An undersaturation with respect to calcium carbonate may promote reactions causing iron pickup and the consequent development of "red water". An oversaturation with respect to calcium carbonate may result in incrustations on utensils and in service pipes, and water heaters.

Alkalinity in the range of 30 to 500 mg/L as calcium carbonate is generally acceptable, but it does not guarantee that problems due to this characteristic within this range,will not occur. The point of chemical stability with respect to alkalinity, may be highly variable in different waters and, from time to time, in the same water. It is therefore suggested that each water be evaluated on its own merit with respect to alkalinity, taking into consideration such factors as the relative amounts of carbonate, bicarbonate and hydroxyl ions, total dissolved solids, calcium and pH.

B.1.2 Aluminum

Aluminum is the third most abundant element in nature, which accounts for its presence in practically all natural waters.

When alum (hydrated aluminum sulphate) is used as a coagulant in water treatment, the measure of residual aluminum in the treated water is important, not only to indicate the efficiency of the treatment process, but also because too high a residual aluminum can result in: (a) distribution system coating with consequent increased energy requirements, (b) interferences for certain industrial processes and (c) after-flocculation leading to consumer complaints.

At present, there is no evidence that aluminum is physiologically harmful and no limit has been specified. A useful guideline to avoid the above problems is to maintain a residual below 0.1 mg/L as Al in the water leaving the plant.

B.1.3 Chloride

Chloride levels in the body are well regulated, and in reasonable concentrations, chloride is not harmful to humans. At concentrations above 250 mg/L, chloride may impart an undesirable taste to water and beverages prepared from water. The maximum desirable concentration of chloride in drinking water is therefore set at 250 mg/L.

B.1.4 Copper

At levels in excess of the maximum desirable concentration, 1.0 mg/L, copper may produce a taste which is objectionable to consumers. Although the intake of large doses of copper has resulted in adverse health effects, the levels at which this occurs are much higher than the maximum desirable concentration. Copper is an essential element in human metabolism.

B.1.5 Hardness

Hardness can have significant aesthetic and economic effects. Water hardness is caused by dissolved polyvalent metallic ions, principally calcium and magnesium, and is expressed as the equivalent quantity of calcium carbonate. On heating, hard waters have a tendency to form scale deposits and can also result in excessive soap consumption. Soft water, on the other hand may result in corrosion of water pipes. Depending on the interaction of other factors such as pH and alkalinity, hardness levels between 80 and 100 mg/L as calcium carbonate ($CaCO_3$) are considered to provide an

acceptable balance between corrosion and incrustation. Water supplies with a hardness greater than 200 mg/L are considered poor but have been tolerated by consumers; those in excess of 500 mg/L are unacceptable for most domestic purposes.

It is well to note that water softening by sodium-ion exchange will introduce additional sodium into drinking water and this additional sodium may constitute a significant percentage of sodium intake if a consumer is required to adhere to a prescribed diet limiting the intake of sodium.

However for the majority of those not on a restricted sodium intake, the additional sodium would not constitute a very significant percentage of the total sodium intake from all sources.

B.1.6 **Iron**

Excessive levels of iron in drinking water supplies are objectionable for a number of reasons. At levels higher than the maximum desirable concentration, 0.3 mg/L, iron may impart a brownish colour to laundered goods; it may produce a bitter, astringent taste in water and beverages; and the precipitation of iron may impart a reddish-brown colour to the water. Excessive iron can also promote the growth of iron bacteria in water mains and service pipes.

B.1.7 **Manganese**

Like iron, manganese is objectionable in water supplies because it stains laundry, and at excessive concentrations causes undesirable tastes in beverages. Difficulties may commence in some waters with a concentration as low as 0.05 mg/L. Manganese may also encourage the buildup of slimy coatings in piping which can slough off as black precipitates.

B.1.8 **pH**

The range of pH in public water systems may have a variety of economic, health and indirect aesthetic effects. The principal objective in controlling pH is to produce water that minimizes corrosion and incrustation. At pH levels above 8.5, mineral incrustations and bitter tastes can occur. Corrosion effects are commonly associated with pH levels below 6.5; elevated levels of certain undesirable chemical substances may result

from the corrosion of specific types of pipe. With pH levels above 8.0, there is also a progressive decrease in the efficiency of chlorine disinfection and alum coagulation processes. The desirable range for drinking water pH is 6.5 to 8.5.

B.1.9 **Sulphates**

The maximum desirable concentration of sulphate in drinking water is 500 mg/L. At levels above this concentration, sulphate can have a laxative effect; however, regular users adapt to high levels of sulphate in drinking water and problems from this effect are usually only experienced by transients and new consumers. The presence of sulphate in drinking water may result in a noticeable taste, the taste threshold concentration depending on associated cations. High levels of sulphate may be associated with calcium, which may contribute to the formation of scale in boilers and heat exchangers. In addition, they may also contribute to the presence of hydrogen sulphide in some types of waters.

B.1.10 **Sulphide**

Although ingestion of large quantities of sulphide has produced toxic effects in humans, it is unlikely that an individual would consume a harmful dose in drinking water because of the associated unpleasant taste and odour. Sulphide is also undesirable in water supplies because in association with soluble iron, it produces black stain on laundered items and black deposits on pipes and fixtures. Sulphide is oxidized to sulphate in well-aerated waters and consequently sulphide levels in public supplies are usually very low. Sulphide levels (expressed as hydrogen sulphide) in water should be inoffensive to the sense of smell and taste.

B.1.11 **Total Dissolved Solids**

The term "total dissolved solids" (TDS), refers mainly to the inorganic substances dissolved in water. The principal constituents of TDS are chloride, sulphates, calcium, magnesium and bicarbonates. The effects of TDS on drinking water quality depend on the levels of its individual components; excessive hardness, taste, mineral deposition, or corrosion are common properties of highly mineralized water. The palatability of drinking water with a TDS level less than 500 mg/L is generally considered to be good.

B.1.12 Zinc

The maximum desirable concentration of zinc in drinking water, 5.0 mg/L has been set on the basis of aesthetic considerations. Water containing zinc at levels greater than 5.0 mg/L tends to be opalescent, develops a greasy film when boiled, and has an undesirable astringent taste. The concentration of zinc in tap water may be considerably higher than in the corresponding source water due to the use of zinc in galvanized pipes. Corrosion control will therefore often minimize the introduction of zinc into drinking water.

B.2 ORGANIC CHEMICAL PARAMETERS – AESTHETIC

High levels of organic matter tend to be associated with colour, taste and odour problems. A large number of individual organic contaminants may be responsible for these problems and it is not practical, except in a few instances, to set limits for specific substances. Maximum desirable concentrations have therefore been specified only for methane, phenols, organic-nitrogen, and the general organics indicator, total organic carbon (TOC).

B.2.1 Methane

Methane contamination may be a problem in well water supplies. Methane occurs naturally in ground water and acts as a stimulant of organic fouling conditions in the distribution system. Methane is not represented in dissolved organic carbon (DOC) analyses and its carbonaceous content is therefore additional to any DOC result. Experience has shown that methane at the maximum desirable concentration, 3 L/m^3, can be controlled by chlorination alone, given a clean distribution system. Also, methane under pressure will come out of solution when the pressure is reduced, resulting in a cloudy appearance in freshly drawn water, but this should not be a problem at methane levels less than the limit. If methane is allowed to accumulate in confined areas, e.g. well pits or parts of distribution systems and plumbing, an explosion hazard may develop.

B.2.2 Organic Nitrogen

Excess organic nitrogen (as represented by the total kjeldahl nitrogen concentration minus the ammonia nitrogen

concentration) may be associated with organic fouling in the distribution system and some types of chlorine-enhanced taste problems. Nitrogen-containing organics are measured in dissolved organic carbon (DOC) determinations but, because of the nutritive value of nitrogen, their contribution to biological fouling is greater than would be suggested from DOC analysis; organic nitrogen at the maximum desirable concentration of 0.15 mg/L would be typically associated with DOC of about 0.6 mg/L. Organic nitrogen compounds frequently contain amine groups which can react with chlorine. Certain chlorinated organic nitrogen compounds may be responsible for flavour problems that are similar to those from chlorophenol tastes and odours. Taste and odour problems have been usually associated with organic nitrogen levels of 0.15 to 0.2 mg/L or greater.

B.2.3 Phenols

The maximum desirable concentration of phenolic substances in drinking water is 0.002 mg/L. This limit has been set primarily to prevent the occurrence of undesirable tastes and odours, particularly in chlorinated water. Chlorophenols may be produced during the chlorination process and have very low taste and odour threshold concentrations; the taste threshold of some chlorophenols may in fact be less than the maximum desirable concentration. Phenol levels in Ontario drinking water supplies are generally less than 0.001 mg/L.

B.2.4 Total Organic Carbon

In previous editions of the **Ontario Drinking Water Objectives** there was a limit on organics based upon a carbon chloroform extract (CCE). The use of the CCE test can no longer be recommended because of the limited fraction of organics thereby detectable and some uncertainty as to what such extracted residues may actually represent. More meaningful tests, now available, include the total organic carbon (TOC) and the closely related dissolved organic carbon (DOC) analyses.

The dissolved organic carbon test measures almost all of the dissolved organic constituents of a water, while the total organic carbon procedure may also include fine suspended particulates and compounds absorbed and any other particulates entering the analytical stream. Where the water

meets or closely approaches the desired turbidity objective, DOC is not measurably different from TOC. Because of procedural advantages possible between TOC and DOC testing, the simpler and less troublesome DOC analysis may be used more frequently to estimate the TOC level in low turbidity samples. Reversion to carefully performed TOC testing, however, may be more relevant in waters containing or developing highly problematic turbidities. Both organic carbon tests normally do not include volatile hydrocarbon gases in their results and low molecular weight haloform compounds are incompletely recovered by present procedures.

High levels of organic carbon in water may result either from excess naturally occurring matter or from man-derived sources, showing a frequent association with colour, taste, odour and turbidity difficulties. Elevated organic levels, although not necessarily a hazard in themselves, may provide precursors for the formation of potentially more harmful contaminants during chlorination. Additionally, high organic levels may develop a potential hazard of conveying biocides and heavy metal ions throughout natural water sources and past water treatment processes.

It should be noted, however, that some waters, even with a low organic content, may still contain minute but hazardous concentrations of toxic organic chemicals. Therefore TOC or DOC is not a direct indicator of possible adverse health effects, and a maximum acceptable concentration for TOC is not specified. However, related to an increased risk of water quality deterioration during storage following accepted treatment practices, a maximum desirable concentration of 5.0 mg/L for TOC (equivalent to clear water DOC) has been derived.

B.3 PHYSICAL PARAMETERS – AESTHETIC

B.3.1 Colour

Colour in drinking water may be due to the presence of natural or synthetic organic substances as well as certain metallic ions such as those of iron, manganese and copper. Metals tend to impart only apparent colour which is usually removable by filtration; on the other hand, organic materials particularly those derived from naturally occurring

substances, may contribute to true colour which is not readily removed by filtration. Colour becomes noticeable to consumers at levels greater than the maximum desirable 5 true colour units (TCU - platinum cobalt scale).

B.3.2 **Odour**

Although an odour can often be attributed to a specific substance, it is usually impractical and often impossible to isolate and identify the odour-producing chemical. Evaluation of this parameter is therefore dependent on individual senses of smell, but because odour cannot be objectively measured, a numerical limit has not been specified. The odour of drinking water should be inoffensive.

B.3.3 **Taste**

Taste and odour are intimately related, and consumers frequently mistake odours for tastes. In general, the sense of taste is most useful in detecting the ionic, inorganic constituents of drinking water, whereas the sense of smell is most useful in detecting covalent, organic constituents. Taste and odour problems constitute the largest category of consumer complaints. Changes in the taste of drinking water may indicate possible contamination of the raw water supply, treatment inadequacies, or contamination of the distribution system. A numerical limit for taste has not been specified because there is no objective method for the measurement of taste and because there is considerable variation among consumers as to which tastes are acceptable. Water provided for public consumption should have an inoffensive taste.

B.3.4 **Temperature**

It is desirable that the temperature of drinking water be less than 15°C; the palatability of water is enhanced by its coolness. Low water temperatures offer a number of other benefits. A temperature below 15°C will tend to reduce the growth of nuisance organisms and hence minimize associated taste, colour, odour and corrosion problems. Low temperature facilitates maintainance of a free chlorine residual by reducing the rates of reaction leading to hypochlorous acid removal. Although low temperature can decrease the efficiency of water treatment processes, this effect may be compensated for by altering the amounts of chemicals used in treatment; low temperature is not a bar to the production of water of an acceptable quality.

APPENDIX C

SUMMARY OF WATER DISINFECTION

Disinfection is the one step in water treatment specifically designed to destroy pathogenic organisms and thereby prevent waterborne diseases. The disinfection agents commonly used in water treatment today are chlorine and its compounds and ozone.

C.1 CHLORINE

Chlorine was introduced as a disinfectant in water treatment around the turn of the century and has become the predominant method for water disinfection. Apart from its effectiveness as a germicide, chlorine offers other benefits such as colour reduction, taste and odour control, suppression of algal growths, and precipitation of iron and manganese. In addition, it is easy to apply, measure, and control; it persists reasonably well and it is relatively inexpensive.

The disinfecting efficiency of chlorine can be diminished by low temperature, high pH, turbidity, ammonia and organic nitrogen, as well as by high levels of iron, manganese, and hydrogen sulphide. These parameters should therefore be determined to evaluate their effect on chlorine disinfection practices. A more detailed discussion can be found in "Chlorination of Potable Water Supplies" MOE Bulletin 65-W-4.

C.1.1 Maintenance of a Free Chlorine Residual

Maintenance of a free chlorine residual throughout the distribution system offers several advantages. It suppresses the growth of organisms within the system; it may afford some protection against small microbiological invasions from outside the system; and the disappearance of the residual, where one was formerly carried, provides an immediate indication of the entry of oxidizable matter into the system or of a malfunction in the treatment process. Because the chlorine residual test is quick and easy to perform, immediate corrective action can be taken. With conventional bacteriological testing, results are not available for at least 24 hours during which time the community may be at risk. It is

recommended that a free chlorine residual be maintained and monitored daily throughout the distribution system.

It is recognized however, that excessive levels of free chlorine may result in taste and odour problems. In these cases, the Ministry shall determine the type and concentration of chlorine residual to ensure a micro-biologically safe water.

C.2 CHLORINE DIOXIDE

Chlorine dioxide offers a number of advantages over chlorine. Its germicidal potency is not affected by ammonia and pH within the usual range for drinking water; it effectively controls phenolic tastes and odours; and it is not known to form trihalomethanes. A potential problem with the use of chlorine dioxide may be the formation of chlorite ion which is reported to have detrimental, but poorly defined, health effects.

C.3 OZONE

In some respects, ozone is a superior disinfectant to chlorine. It is unaffected by the pH or ammonia content of the water and it is more effective than chlorine against viruses, cysts, fungi and spores. However, ozone is unstable and as a result, ozone residuals cannot be maintained for long periods of time. Chlorine must therefore be added after disinfection with ozone in order to provide a residual which can be maintained throughout the distribution system.

GLOSSARY

Aesthetic – Refers to those aspects of drinking water quality that are perceivable by the senses, namely taste, odour, colour and clarity.

Algae – Comparatively simple chlorophyll-bearing plants most of which are aquatic and microscopic in size.

Alpha particle – A charged particle emitted from the nucleus of an atom and having a mass and charge identical to a helium nucleus. Gross alpha particle activity is the total radioactivity from alpha particle emission as inferred from measurements on a dry sample.

Bacteria – Microscopic single-celled micro-organisms which can be distinguished from higher organisms by their size range (diameters are usually in the range of 1.0 um) and the absence of a true cell nucleus (procaryotic cell construction).

Becquerel (Bq) – A unit of radioactivity which expresses the rate of disintegration of a radionuclide; one becquerel equals one nuclear transformation per second and corresponds to approximately 27 picocuries.

Beta particle – Charged particle emitted from the nucleus of an atom with the mass and charge of an electron. Gross beta particle activity is the total radioactivity resulting from beta particle emission as inferred from measurements on a dry sample.

Biocide – A chemical substance which at relatively low dose levels is capable of killing living organisms.

Cholinergic – Stimulated, activated, or transmitted by acetylcholine. Neurons in which nerve impulses are mediated by acetylcholine are known as cholinergic neurons.

Cholinesterase – An esterase (enzyme) present in all body tissues which hydrolyses acetylcholine into choline and acetic acid. Acetylcholine is a neurotransmitter, and therefore substances that impair the function of cholinesterase enzymes are neurotoxic.

Coagulation – A water treatment process in which chemicals are added to combine with or entrap suspended and colloidal particles to form rapidly settling aggregates. The process may be separated into two phases, "mixing" and "flocculation".

Colloid – Particulate or insoluble material in a finely divided form that remains dispersed in a liquid for an extended time period. Coagulation is required for clarification of turbid colloidal dispersions.

Contamination – The introduction of materials which makes otherwise potable water unfit or less acceptable for use.

Criteria – The scientific data used as a basis for maximum acceptable concentrations.

Cross-connection – In plumbing, a physical connection between two different water systems.

Disinfection – Effective killing by chemical or physical processes of all organisms capable of causing disease.

Dysentery – Disease characterized by inflammation of the intestinal mucous membrane and glands; diarrhea is commonly a symptom of dysentery.

Filter – A porous media through which a liquid may be passed to effect removal of suspended materials.

Flatulence – The presence of excessive amounts of air or gases in the stomach or intestine, leading to distension of the organs.

Flocculation – The process by which suspended colloidal or very fine particles coalesce and agglomerate into well-defined hydrated floccules of sufficient size to settle readily; the stirring of water after coagulant chemicals have been added to promote the formation of particles that will settle.

FTU-(Formazin Turbidity Unit) – Unit of measure for turbidity in a water sample. A formazin standard solution is prepared by dissolving 5 g hydrazine sulphate and 50 g hexamethylenetetramine in 1 litre of distilled water; after standing for 48 hours a solution prepared in this way has a turbidity value of 4,000 units.

Fungi – Nonphotosynthetic micro-organisms which include yeasts and molds.

Gamma Radiation – Short wavelength electromagnetic radiation emitted from the atomic nucleus.

Ground Water – Water located below the water table in the saturated zone of the earth's crust.

Humic Substances – Major constituents of soil; the dissolved organic colouring material in water is almost totally made up of humic substances. Humic substances are divided into two classifications on the basis of their solubilities: humic and fulvic acids.

Incrustation – The deposition of a crust or hard coating on a surface.

Limits – The limits in this document are the recommended minimum requirements for the provision of safe, palatable, and aesthetically appealing drinking water.

Macro-organisms – Aquatic organisms that can be seen without the aid of a microscope which can include copepods, cladocerans, oligochaetes, molluscs and aquatic insects.

Membrane Filter (MF) Technique – A method for the enumeration of bacteria in water. A measured volume of water is filtered through a sterilized membrane which is then transferred to the surface of an appropriate agar medium and incubated. Upon incubation, retained bacteria give rise to visible colonies on the membrane surface.

Micro-organism – A microscopic organism, including bacteria, protozoa, fungi, viruses and algae.

Most Probable Number (MPN) Procedure – A method for estimating the density of coliform bacteria in water. Measured volumes of a water sample are inoculated into tubes containing an appropriate medium. The presence of gas after 48 hours incubation constitutes a positive presumptive test. Results are reported as a Most Probable Number (MPN). The MPN is a statistical estimate of the number of bacteria that more probably than any other would give the observed result; it is not an actual count of the bacteria.

Nematode – A member of the class Nematoda, the roundworms, some of which are parasites. Free-living nematodes are abundant in soil and water.

NTU (Nephelometric Turbidity Unit) - See FTU

Picocurie – 10^{-12} curies, where a curie is the unit of radioactivity contained in any quantity of material yielding 3.7 x 10^{-10} radioactive disintegrations per second.

Presence-Absence (P-A) Test – a modification of the MPN procedure, employing only one analysis bottle per sample; 50 or 100 ml of sample water is inoculated into a bottle containing a lactose broth medium (HAMES). If growth occurs with the production of acid and/or gas, then other tests are used to determine the types of bacteria present; they may include coliforms, fecal coliforms, fecal steptococci, **P. aeruginosa, S. aureus, & Aeromonas sp.**

Palatable – Pleasing to the taste.

Parameter – Measurable or quantifiable characteristic or feature.

Pathogen – An organism capable of eliciting disease symptoms in another organism.

Pesticide – A substance or mixture of substances used to kill unwanted species of plants or animals.

pH – An index of hydrogen ion activity, pH is defined as the negative logarithm of hydrogen ion concentration in moles per litre. A solution of pH 0 to less than 7 is acid, pH of 7 is neutral, pH over 7 to 14 is alkaline.

Pollution (water) – Anything causing or inducing objectionable conditions in any watercourse and affecting adversely the environment and use or uses to which the water thereof may be put.

Potable Water – Water fit for human consumption.

Protozoa – Unicellular, nonphotosynthetic, nucleated organisms, such as amoeba, ciliates and flagellates. Commonly aquatic and generally deriving most of their nutrition from preformed organic food.

Raw Water – Surface or ground water that is available as a source of drinking water but has not received any treatment.

Radioactive – Capable of emitting radioactivity, the spontaneous nuclear disintegration with emission of corpuscular or electromagnetic radiation or both.

Radionuclide – A nuclide is a species of atom characterized by the constitution of its nucleus. The nuclear constitution is specified by the number of protons and neutrons, and energy content; or alternatively by the atomic number, mass number, and atomic mass. Radionuclides are radioactive nuclides. To be considered as a distinct nuclide, the atom must be capable of existing for a measurable time.

Sanitary Survey – A survey and analysis of the physical environment for the purpose of identifying existing and potential sources of health hazards and environmental contamination.

Spore – A reproductive unit, lacking a preformed embryo, that is capable of germinating directly to form a new individual. A resistant body formed by certain micro-organisms; a resistant resting cell; a primitive unicellular reproductive body.

Surface Water – Water that rests upon the earth's surface.

TCU (True Colour Units) – A measurement of colour on the platinum cobalt scale. The colour of water resulting from substances which are totally in solution not to be mistaken for apparent colour resulting from colloidal or suspended matter.

Virus – An obligate intracellular parasitic micro-organism; viruses are sharply differentiated from all cellular organisms as a virus particle consists simply of a nucleic acid molecule enclosed in a protein coat which in some cases is surrounded by a membrane or envelope. Viruses have no independent metabolism.

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